Appendix C

Hazardous Materials

Oil Spill Trajectory Analysis
Fault Trees
Major Oil Spills in US Waters

Oil Spill Trajectory Modeling

C.1 Background

This appendix presents the results of pat drifter and trajectory studies and oil spill modeling conducted for Platform Irene and the Platform Irene to LOGP offshore pipeline. The modeling was conducted to determine the movement and fate of an oil spill occurring at either of these two locations. Two models were examined, the Minerals Management Service (MMS) Oil Spill Risk Analysis (OSRA) and the General National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA) Oil Modeling Environment (GNOME). Each are publicly available models.

C.2 Drifter Studies

The trajectories of drifters released near the project area generally reflect the surface flow patterns measured by long-term current-meter moorings (Crowe and Schwarzlose, 1972; Schwartzlose and Reid, 1972; Chelton, 1987; Winant et al., 1999). Namely, northwestward transport is observed throughout much of the year except during strong upwelling events that are most prevalent between April and June. Prevailing winds near Point Arguello are directed to the southeast except during brief, three-to-four-day periods when winter storms disrupt the normal pattern as they pass through the region. Surface currents near the project area are generally directed to the northwest, in opposition to, and uncoupled with the prevailing southeastward winds (Savoie et al., 1991; SAIC, 1995). During the spring and early summer, brief episodes of intensified southward-directed winds result in a reversal of surface currents. For periods of up to a week, near-surface flows turn toward the southeast in opposition to the northwestward current direction that is maintained throughout most of the water column.

The opposing directions of the wind and surface currents near Point Arguello are evident in drifter studies. CalCOFI drifter bottles released north of the Santa Barbara Channel in December 1969 migrated northward at speeds exceeding 15 cm/s. However at other times of the year, drift bottles released near Point Conception were recovered both to the north and to the south near San Diego. For release points near Point Arguello in 1984, many of the CCCCS surface drifters traveled south in response to strong southward directed winds (Chelton, 1987). It was only during a brief period when southward winds weakened in July that the majority of drifters moved northward. However, the CCCCS drifter design is susceptible to a downwind motion of about 0.5% of the wind speed and thus may not accurately represent surface currents alone.

The drifters used in the Santa Barbara Channel to Santa Maria Basin (SMB) coastal circulation study were designed to minimize the influence of wind and wave drift in favor of tracking surface currents over a depth of about 1 m (Davis et al., 1982). As a result, flow statistics derived from the drifters compared well with that of the moored current meters (Dever et al., 1998). Discrepancies in mean flow direction have been ascribed to sampling bias (Dever, 2001b). Beginning in January 1995, many of these drifters were deployed within the Santa Maria Basin, including locations near the Tranquillon Ridge Field. Few of the drifters released near the Point Arguello to Point Conception region beached before exiting the region (Dever et al., 2000; Winant et al., 1999). In a manner consistent with the long-term current meter data collected as part of CaMP, initial offshore movement was followed by northward movement into the SMB in fall and winter. Spring and summer deployments were more likely to show southward flow toward San Miguel Island. Few drifters moved eastward into the Santa Barbara Channel.

The complex interaction between winds and surface currents near Point Conception makes predictions of oil spill trajectories difficult. During much of the year, but especially in the fall and winter, the northwestward surface flow is in direct opposition to the prevailing winds. Certainly these surface currents, as determined by current meters and drifters, have a direct bearing on the fate and effects of potential oil spills resulting from the proposed project. However, winds also influence the spread and trajectory of oil slicks on the sea surface. Empirical data from the open ocean suggests that leading edge of an oil slick would drift at about 3% of the wind speed and oil-following drifters have been evaluated based on their ability to match this “3% rule” (Reed et al., 1988). However, there is no rigorously defensible theoretical basis or empirical data to support the application of this rule in coastal flow regimes.

Drifters deployed during the Santa Barbara Channel to Santa Maria Basin coastal circulation study tended to travel toward the south only about 31% of the time and only about 15% of these intersected the shoreline.

Drifters, with their measurable mass and finite vertical profile below the sea surface, cannot capture the behavior of an oil slick that is typically only a few millimeters thick (Reed et al., 1988). Furthermore, dispersion and weathering affect the spread of oil on the sea surface, and buoys cannot capture the changing slick dynamics across a wide range of winds, waves, and currents. Goodman et al. (1995) tested the oil-tracking ability of several drifter designs, including the Davis et al. (1982) design used in the Santa Barbara Channel-SMB coastal circulation study. They found that Davis-type drifters lagged behind simulated oil slicks presumably because they are optimized to track surface currents with minimal influence by winds and waves. In cases where winds opposed surface currents, the Davis-type drifters moved into the prevailing wind and in a direction opposite of the simulated oil slicks made from wood chips. This is similar to the case in the southern SMB where the northward-flowing Davidson current often opposes the prevailing southward-directed winds.

C.3 MMS OSRA Model

The oil-spill risk analyses described in this evaluation were performed using the MMS numerical Oil Spill Risk Analysis (OSRA) model for the Pacific Region. It calculates probabilities of shoreline impact, as well as ocean area impact, after applying a drift equivalent to 3.5% of the prevailing wind velocity in its trajectory computations. Because of the heavy influence of southward-directed winds near Point Conception, the model results indicate that the probability of shoreline impacts along the Channel Islands to the south is far higher than at sites along the central coast to the north. The influence of southward directed winds in the model effectively overcomes the northwestward surface currents observed over part of the year in the field programs. This contrasts with other drifter studies which tend to show travel toward the south only about 31% of the time and only about 15% of these intersect the shoreline (Browne, 2001). In Browne's analysis, northward transport has a slight edge with 32% of the trajectories traveling to the north and contacting the coast about 23% of the time. For more discussion on surface transport and drifters, please see Section 5.6, Oceanography and Marine Water Quality, in this EIR.

The OSRA Model utilizes a seasonally averaged ocean currents for four seasons: winter, spring, summer and fall. The seasonally average current fields are provided by Scripps Institution of Oceanography and are based on several years of current meter and free-floating drifter data. Shoreline segments are divided into their respective quad areas and the probability of impact on each quad is calculated. Weathering factors are not addressed.

The use of the seasonal average ocean currents tends to smooth out the effect of the northward currents which may occur and thereby reduce the northward movement of the trajectories.

The complexity of opposing winds and currents near the project area makes the reconciliation between OSRA model results and drifter observations difficult. Because the applicability of the "3.5% wind rule" in complex coastal flow regimes has not been rigorously quantified, this environmental evaluation also addressed the GNOME model which indicates more northward impacts (see following section) due to its separation of flow regimes.

However, drifters, with their measurable mass and finite vertical profile below the sea surface, cannot capture the behavior of an oil slick that is typically only a few millimeters thick (Reed et al., 1988). Newer style drifters (called "oil following") have been deployed recently and may provide better data when available. Furthermore, dispersion and weathering affects the spread of oil on the sea surface, and buoys cannot capture the changing slick dynamics across a wide range of winds, waves, and currents.

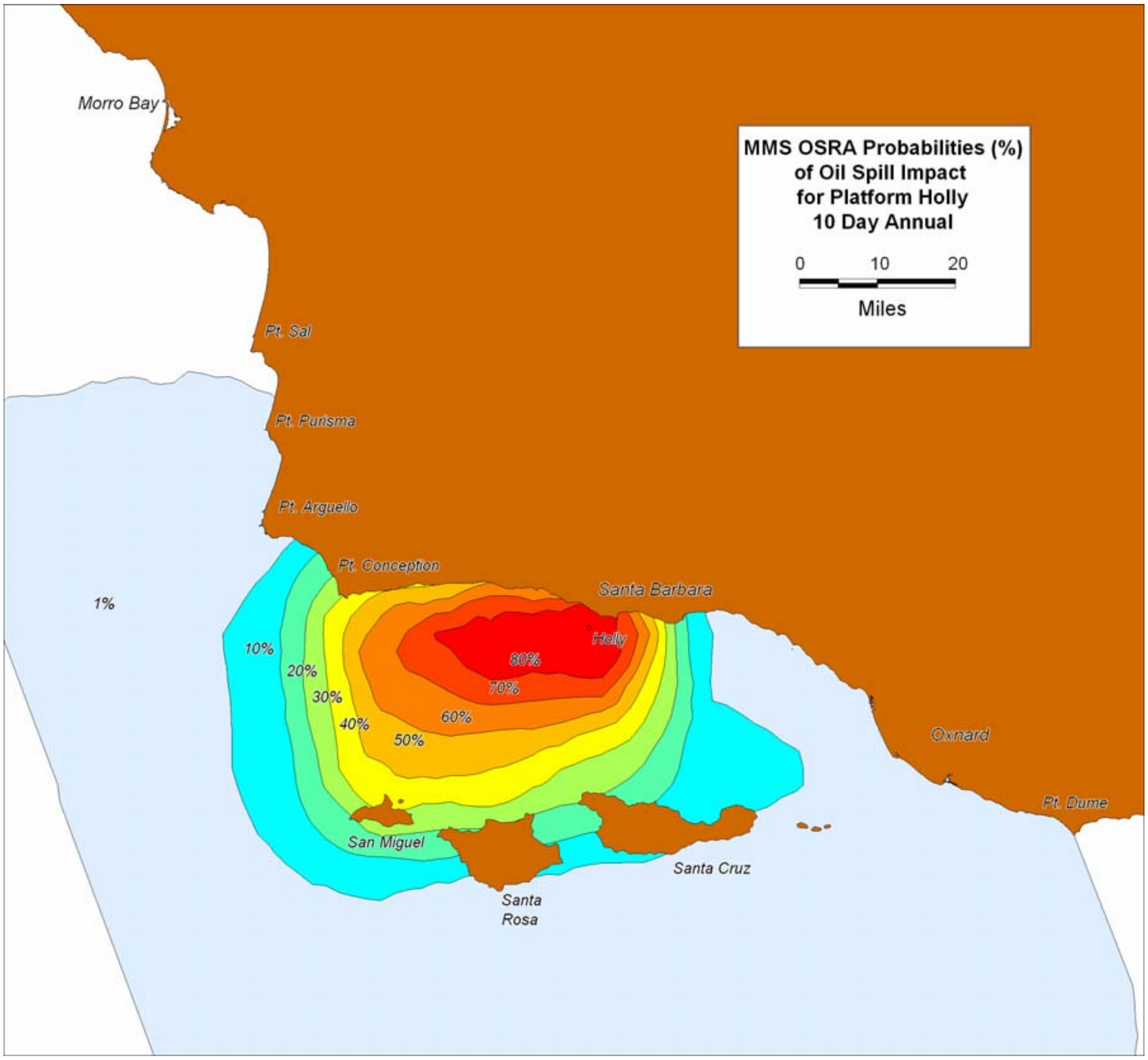
C.4 OSRA Results

The MMS has developed OSRA reports for the Pacific Region OCS, amongst other regions. Because oil spills may occur from activities associated with offshore oil exploration, production, and transportation, the MMS conducts a formal risk assessment to evaluate the risk of oil spill contact from existing and proposed oil and gas operations. Contact is evaluated at each block in a grid encompassing the entire ocean region as well as grids located along the shoreline. Risks are examined for spills from 23 OCS platforms, 11 pipelines, 10 potentially developed units and the transportation routes. The analysis assumes that a spill has occurred and estimates the trajectories of the hypothetical oil spills from potential accident sites to land and ocean segment locations. It then provides conditional probabilities of oil impacting a given area.

The trajectory simulation portion of the MMS OSRA model consists of many hypothetical oil-spill trajectories. The trajectories are the consequence of the integrated action of temporally and spatially varying wind and ocean current fields on the hypothetical oil spills. Collectively, they represent a statistical set of the winds and currents that will occur over the life of the production period. The analysis uses a combination of observed and theoretically computed ocean currents and winds. Most of the ocean currents used were generated by a numerical model. They were supplemented with many direct observations of the currents in the Santa Barbara Channel resulting from deployments of surface drifting buoys. The sea surface winds over the study area were derived from an atmospheric model and from measured winds at buoy, platform, island and land-based wind stations. The studies are conducted for four seasons (winter, spring, summer and fall) when currents and winds are different. More information on the study is available at the MMS web site.

Results of the oil spill trajectory model are presented below for Platform Holly. The pipeline and the EMT were not analyzed by the MMS. However, given the area encompassed by the spills, spills from the EMT would produce similar results as those from Holly. The figure shows the conditional probabilities of oil impacting different locations on the ocean and the land segments.

The OSRA trajectory analysis indicates that, generally, an oil spill would travel to the north and south of the spill, impacting ocean areas from north to Point Purism, and south to the Channel Islands and Point Dume.


MMS OSRA Probabilities (%)
of Oil Spill Impact
for Platform Holly
10 Day Annual
0
10
20
Miles
Morro Bay
Pt. Sal
Pt. Purisma
Pt. Arguello
Pt. Conception
Santa Barbara
Holly
Oxnard
Pt. Dume
1%
10%
20%
30%
40%
50%
60%
70%
80%
San Miguel
Santa Rosa
Santa Cruz

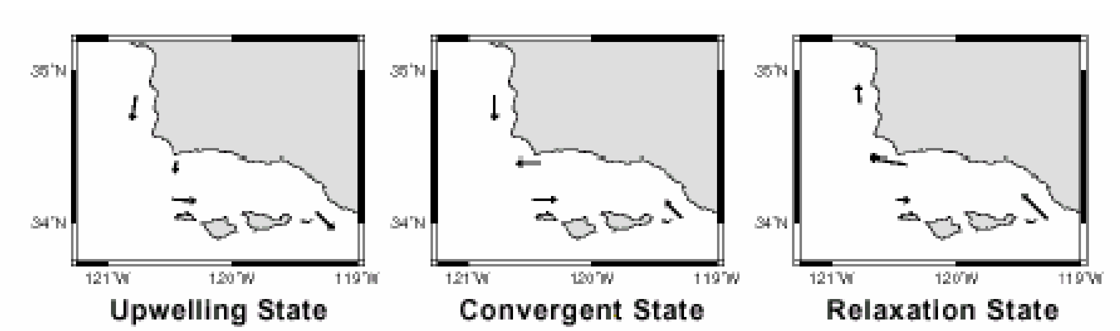
C.5 GNOME Model

GNOME is a publicly available oil spill trajectory model that simulates oil movement due to winds, currents, tides, and spreading. GNOME was developed by the Hazardous Materials Response Division (HAZMAT) of the NOAA OR&R (NOAA 2002).

The GNOME Model includes variables that account for weatherization of the released materials as well as a separate set of ocean current regimes for the Santa Barbara Channel and SMB. Wind speed and direction as well as variability can be input to the model. This enables the analysis of specific spill situations with given meteorological conditions. However, in order to assess the probabilities of a specific modeled end result, wind distributions and ocean current time dependant distributions would need to be obtained and many modeling runs conducted for the area.

The GNOME model operates by generating “splots” associated with each spill scenario. The fate of the splots is either to remain on the water, to be beached, to be weathered and disappear or to travel out of the modeling space. The movement of the splots is defined by the ocean current “regime” and the wind influences.

Ocean currents in GNOME are essentially divided into three regimes for the Santa Barbara Channel and the Santa Maria Basin: upwelling, convergent and relaxation. Each of these is shown figuratively below.



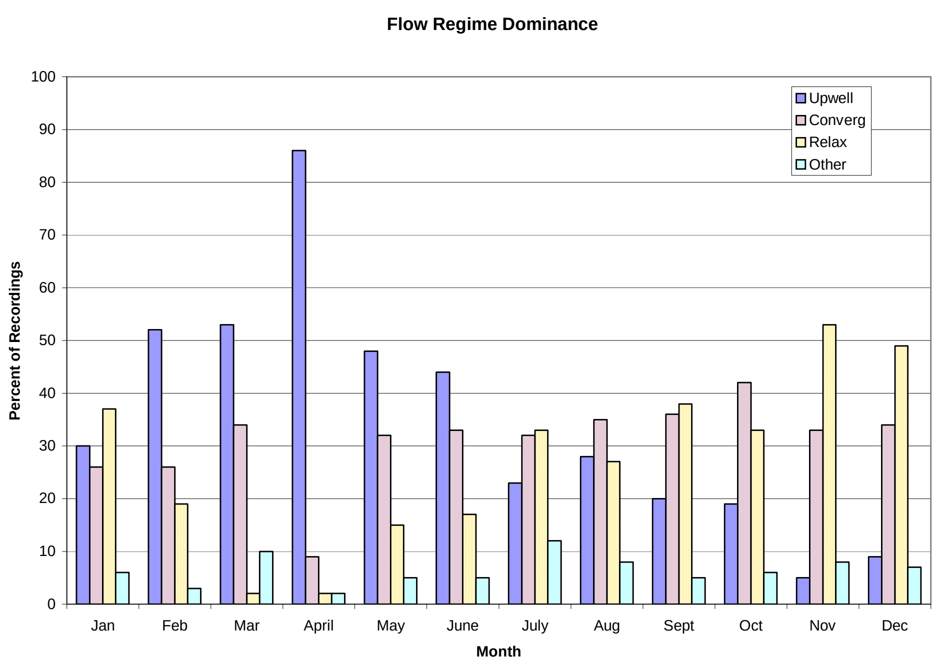
Upwelling
The upwelling state is named for the upwelling of cold (approximately 11°C) subsurface waters near Point Conception that often accompanies this state. The upwelling state occurs primarily in spring, although it has also been observed in other seasons. In terms of the conceptual models of the momentum balance, the upwelling state occurs when strong (>10 m/s), persistent (several days or more), upwelling favorable (equatorward) winds overwhelm any poleward, along-shelf pressure gradient.

Convergent
The convergent state is named for the convergence of southward flow west of Point Arguello with westward flow south of Point Conception. The convergent state occurs primarily in summer, although it has also been observed in other seasons. In terms of the conceptual models of the momentum balance, the convergent state tends to occur

when upwelling favorable winds and a strong poleward, along-shelf pressure gradient exist. The most characteristic feature of the resulting flow field is a strong cyclonic recirculation in the western Santa Barbara Channel with about equal strength in the northern and southern limbs of the recirculation.

Relaxation
The relaxation state is named for the time periods when winds off Point Conception “relax” from their usual equatorward direction. The relaxation state occurs primarily in fall and early winter. In terms of the conceptual models of the momentum balance, the relaxation state occurs when poleward, along-shelf pressure gradients overwhelm upwelling favorable or weak winds. The most characteristic feature of the resulting flow field is a strong westward flow (>50 cm/s) through the Santa Barbara Channel and to the SMB. Flow in the SMB is strongest along the mainland coast

Each of the three ocean current states includes a counter-clockwise circulation pattern in the Santa Barbara Channel. The frequency of occurrence of each flow regime is shown below.



C.6 GNOME Model Results

The GNOME model was run for the same oceanographic and meteorological conditions as were modeled in the MMS Report, Delineation Drilling Activities in Federal Waters Offshore Santa Barbara, California: Draft Environmental Impact Statement, 2001 (MMS 2001-046). These conditions are summarized below:

Current Regime	Meteorological Conditions	Timeframe
Upwelling	8 m/s NW	3 days 10 days
Convergent	7 m/s NW	3 days 10 days
Relaxation	4 m/s NW 4 m/s SW 0 m/s	3 days 10 days

These meteorological conditions are not intended to be all encompassing of the meteorological conditions that could be present during a spill scenario. Although the GNOME model takes ocean currents into account to a large degree, wind effects still have a large influence.

The model was run for releases at the Barge Jovalan mooring location.

Flow Regimes
The figure shows the strong influence of the flow regime on the fate of the oil spilled. For the convergent and upwelling scenarios, occurring most frequently during the spring and summer, these two regimes produce oil spills that move in the southern direction impacting San Migual, Santa Rosa and the Santa Cruz Islands and points along the coast further south (the model does not run past Oxnard). The counter-clockwise currents in the Santa Barbara Channel prevent oil from impacting the Coastline north of Point Conception. For the relaxation periods, occurring during the fall and winter, the flows bring the oil north impacting areas a far north as Point Sal.

Time Period
Two timeframes were examined in the modeling: 3 days and 10 days. This was conducted in correlation with the MMS study (MMS-2001-046). The model indicated that after 3 days, impacts would range as far south as the Channel Islands. Northward movement after 3 days during relaxation regimes would move as far north as Pt. Conception. After 10 days, impacts would reach at least the Channel Islands to the South and Point Sal to the north. These impacts shown are only for a limited set of meteorological conditions.

Wind Direction
Releases were modeled for three wind directions correlated with the ocean current flow regimes. Winds from the south-west were modeled along with the relaxation regimes, winds from the northwest were modeled along with the upwelling and convergent regimes, and neutral winds were modeled with the relaxation regime. The wind direction figure shows the importance of wind direction as south-west winds drove the spilled oil into the coastline. Winds from the north-west moved the oil towards the south impacting the Channel Islands. Neutral winds followed the flow regime, in this case relaxation, a moved primarily towards the north impacting the coastline north to Pt. Sal. Wind

directions between any of those modeled (such as SSW) would impact areas between those indicated above.

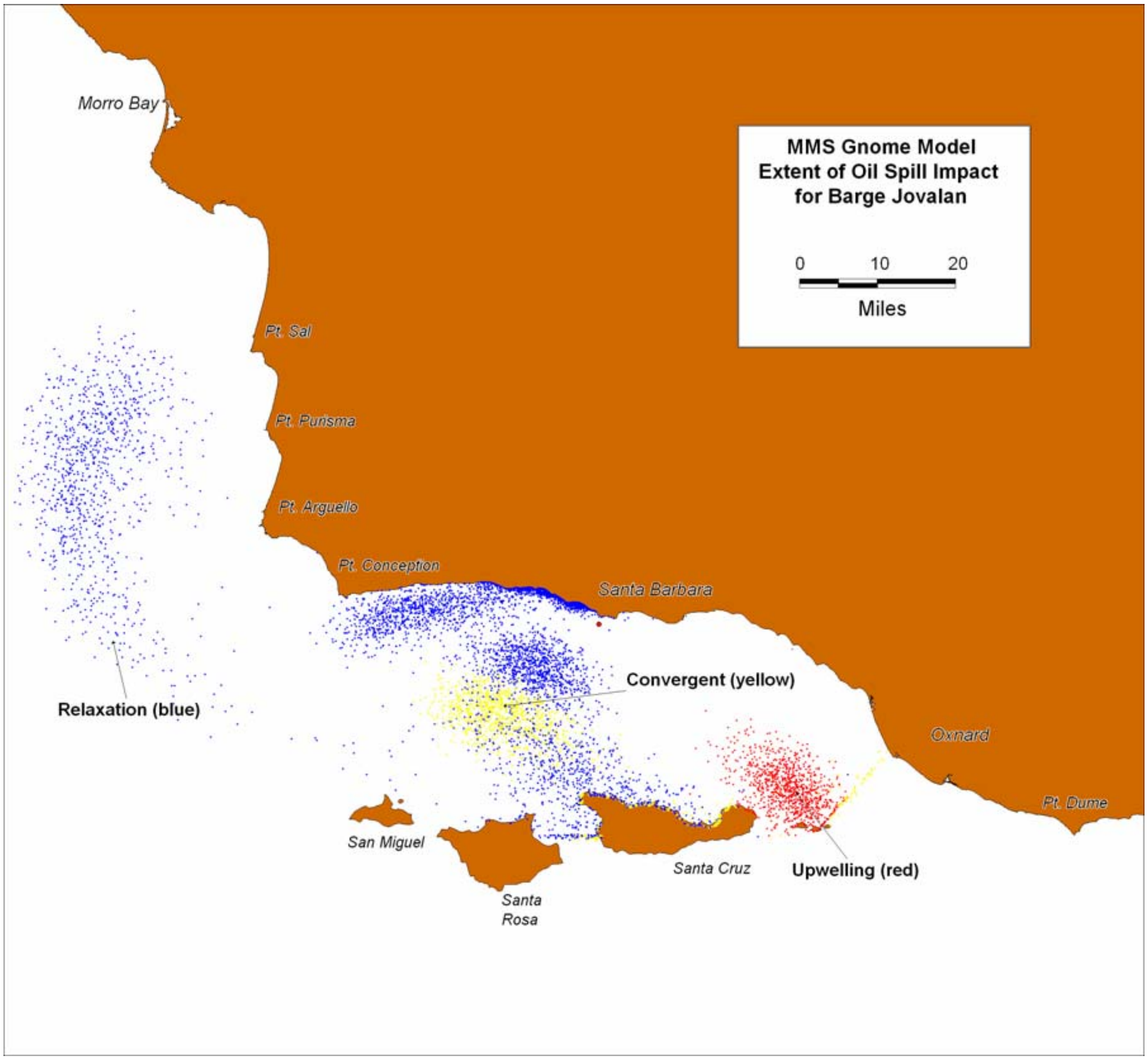
Operating Scenarios and Impact Levels
The GNOME Model produces output which allows for quantifying the amount of oil that is either beached, left on the water, weathered or that is outside the scope of the model area. Current operating scenarios have the potential to beach a maximum of about 69% of the oil spilled. Worst case impacts associated with a release would occur during a relaxation regime.

C.7 Uncertainties

Both the GNOME model and the MMS OSRA model has a number of uncertainties. The winds and currents used in the models are averages of current data seasonally (OSRA) or by modeling characteristic current regimes (GNOME). This oversimplifies spill trajectories by canceling out the range of spatial and temporal variability of current patterns. Modeling spills under average or typical conditions may distort the consequences, because some types of mishaps may be most likely to occur during extreme meteorological conditions.

Intermittent cross-shelf currents can drive spills directly toward shore on the South Coast as described in Ohlman, 2005. In addition, the OSRA and GNOME modeling assume that the oil is released at the ocean surface. However, loading line releases would occur at the sea floor, requiring a different modeling approach. However, the MMS POSVCM model allows for modeling of sub-sea pipeline releases. This model demonstrates that only a very small amount of the oil is dispersed before reaching the surface. With shallow pipelines, such as the loading line, the resulting sheen is similar to a release at the surface.

Spill models are very complex and involve a number of uncertainties and generalized characteristics, given the complex and variable winds and currents in the S.B. Channel.



MMS Gnome Model
Extent of Oil Spill Impact
for Barge Jovalan
0
10
20
Miles
Morro Bay
Pt. Sal
Pt. Purisma
Pt. Arguello
Pt. Conception
Santa Barbara
Oxnard
Pt. Dume
Relaxation (blue)
Convergent (yellow)
Upwelling (red)
San Miguel
Santa Rosa
Santa Cruz

EMT, Line 96 and Loading Line Faultrees: Current Operations

Summary of Frequency Inputs					
Lifetime of project	10	years			
Average oil production over lifetime, bpd	4100	bpd over lifetime (oil only)			
Number of annual barge visits	23	per year			
Hours of loading per barge visit	20	hours			
Loading rate, bph	4200	bph			
Pipelines and EMT Summary Failure Rate and Probability Summary					
Scenario	***Freq, per year***	***Lifetime Prob, %***			***Notes***
Leaks to Land Envir (not incl berm)	4.67E-02	37.3			line 96, loading line land, EMT piping no berm
Ruptures and Large Spills to Land Envir (not incl berm)	6.53E-03	6.3			line 96, loading line land, EMT piping no berm
Ruptures and Large Spills to Land Envir (within Tanks and pump berms)	4.79E-04	0.5			Crude tanks, valving within berm, pumps
Leaks and Small Spills to Ocean	1.75E-01	82.6			10" pipeline, hose line, barge
Ruptures and Large Spills to Ocean	1.07E-02	10.2			10" pipeline, hose line, barge
Total Leaks and Small Spills (not incl berm)	2.21E-01	89.1			All leaks, except crude tanks and pumps
Total Ruptures and Large Spills (not incl berm)	1.73E-02	15.9			All ruptures, except crude tanks and pumps
Detailed Calculations					
Description	***Base rate***	***Units***	***Multiplyer***	***Freq/yr***	***Reference or Probability over Project Lifetime***
PIPELINE FAILURE RATES					
Pipeline Only					
Loading Line Pipeline - Land Rate (12" portion)					
CSFM for this pipeline, leak	5.64E-02	per mile-year	0.15	8.28E-03	7.9
CSFM for this pipeline, rupture	1.02E-02	per mile-year	0.15	1.49E-03	1.5
Loading Line Pipeline - Ocean Rate (10" portion)					
CSFM for this pipeline, leak	5.64E-02	per mile-year	0.54	3.02E-02	26.0
CSFM for this pipeline, rupture	1.02E-02	per mile-year	0.54	5.43E-03	5.3
Line 96 Pipeline - Failure rates					
CSFM for this pipeline, leak	1.13E-02	per mile-year	3.1	3.50E-02	29.6
CSFM for this pipeline, rupture	2.03E-03	per mile-year	3.1	6.31E-03	6.1
Line 96 SCADA - failure				***1.93E-03***	***1.9***
Phone line failure	2.28E-04	demand	1	2.28E-04	Estimated 8 hours per year down time
Pump shutdown failure	1.00E-04	on demand	1	1.00E-04	Rijnonmd, failure to stop on demand
Actuated valve failure	1.00E-03	on demand	1	1.00E-03	Lees, failure to operate on demand
Pressure Switch	1.00E-04	on demand	1	1.00E-04	Rijnonmd, failure on demand
Operator Restarts system, override SCADA	5.00E-04	on demand	1	5.00E-04	Rijnmond, falilure to take action on an alarm. Conditions to inspect line after each alarm.

EMT, Line 96 and Loading Line Faultrees: Current Operations

PIPELINE AND COMPONENT FAILURE RATES					
Description	***Base rate***	***Units***	***Multiplyer***	***Freq/yr***	***Reference or Probability over Project Lifetime***
Summary					
Line 96 leak				3.55E-02	29.9
Line 96 rupture				6.35E-03	6.2
Loading line leak to land (includes leak at all times and ruptures when not operating)				1.14E-02	10.8
Loading line leak to ocean (includes leak at all times and ruptures when not operating)				1.80E-01	83.5
Loading line rupture to land (includes only ruptures when operating)				8.01E-05	0.1
Loading line rupture to ocean (includes only ruptures when operating)				8.63E-04	0.9
Loading line leak				1.92E-01	85.3
Loading line rupture				9.43E-04	0.9
Loading Line Pipeline - Land portion - Leak- not operating				***9.55E-03***	***9.1***
Pipeline Leak				8.28E-03	
Leak at large valve	7.88E-05	/valve.yr	3	2.37E-04	
Rupture of small valve	8.76E-06	/valve.yr	5	4.38E-05	
Pipeline Rupture				1.49E-03	
Full bore valve rupture	8.76E-06	/valve.yr	3	2.63E-05	
Operational fraction	5.25E-02	on demand	1	5.25E-02	Based on the time of barge loading
Loading Line Pipeline - Land portion - Rupture not operating				***1.45E-03***	***1.4***
Pipeline Rupture				1.49E-03	
Full bore valve rupture	8.76E-06	/valve.yr	4	3.50E-05	
Operational fraction	5.25E-02	on demand	1	5.25E-02	Based on the time of barge loading
Loading Line Pipeline - Land portion - Leak while operating				***4.49E-04***	***0.4***
Pipeline Leak				8.28E-03	
Leak at large valve	7.88E-05	/valve.yr	3	2.37E-04	
Rupture of small valve	8.76E-06	/valve.yr	5	4.38E-05	
Operational fraction	5.25E-02	on demand	1	5.25E-02	Based on the time of barge loading
Loading Line Pipeline - Land portion - Rupture while operating				***8.01E-05***	***0.1***
Pipeline Rupture				1.49E-03	
Full bore valve rupture	8.76E-06	/valve.yr	4	3.50E-05	
Operational fraction	5.25E-02	on demand	1	5.25E-02	Based on the time of barge loading
Loading Line Pipeline - Ocean portion - Leak- not operating				***1.57E-01***	***79.3***
Pipeline Leak				3.02E-02	
Leak from hose	1.10E-01	/hose-yr	1	1.10E-01	CCPS 89 for rupture. Assume 10% rupture and annual maintenace
Leak from hose flanges	8.76E-05	/flange-yr	7	6.13E-04	
Leak at large valve	7.88E-05	/valve.yr	1	7.88E-05	
Rupture of small valve	8.76E-06	/valve.yr	0	0.00E+00	
Pipeline Rupture				5.43E-03	
Rupture from hose	1.10E-02	/hose-yr	1	1.10E-02	CCPS 89 for rupture. Assume 10% rupture and annual maintenace
Full bore valve rupture	8.76E-06	/valve.yr	1	8.76E-06	

EMT, Line 96 and Loading Line Faultrees: Current Operations

Description	*Base rate*	*Units*	*Multiplyer*	*Freq/yr*	*Reference or Probability over Project Lifetime*
Loading Line Pipeline - Ocean portion - Rupture not operating				***1.56E-02***	***14.4***
Pipeline Rupture				5.43E-03	
Rupture from hose	1.10E-02	/hose-yr	1	1.10E-02	CCPS 89 for rupture. Assume 10% rupture and annual maintenace
Full bore valve rupture	8.76E-06	/valve.yr	1	8.76E-06	
Operational fraction	5.25E-02	on demand	1	5.25E-02	Based on the time of barge loading
Loading Line Pipeline - Ocean portion - Leak while operating				***7.40E-03***	***7.1***
Pipeline Leak				3.02E-02	
Leak from hose	1.10E-01	/hose-yr	1	1.10E-01	CCPS 89 for rupture. Assume 10% rupture and annual maintenace
Leak from hose flanges	8.76E-05	/flange-yr	7	6.13E-04	
Leak at large valve	7.88E-05	/valve.yr	1	7.88E-05	
Rupture of small valve	8.76E-06	/valve.yr	0	0.00E+00	
Operational fraction	5.25E-02	on demand	1	5.25E-02	Based on the time of barge loading
Loading Line Pipeline - Ocean portion - Rupture while operating				***8.63E-04***	***0.9***
Pipeline Rupture				5.43E-03	
Rupture from hose	1.10E-02	/hose-yr	1	1.10E-02	CCPS 89 for rupture. Assume 10% rupture and annual maintenace
Full bore valve rupture	8.76E-06	/valve.yr	1	8.76E-06	
Operational fraction	5.25E-02	on demand	1	5.25E-02	Based on the time of barge loading
Line 96 Pipeline - Leak				***3.55E-02***	***29.9***
Pipeline Leak				3.50E-02	
Leak at large valve	7.88E-05	/valve.yr	5	3.94E-04	
Rupture of small valve	8.76E-06	/valve.yr	10	8.76E-05	
Line 96 Pipeline - Rupture				***6.35E-03***	***6.2***
Pipeline Rupture				6.31E-03	
Full bore valve rupture	8.76E-06	/valve.yr	5	4.38E-05	
EMT FAILURE RATES				**Freq/yr**	
Summary					
Rupture of crude oil piping - outside of berms				1.01E-04	0.1
Leak from crude oil piping - outside of berms				1.15E-03	1.1
Equipment Rupture - Inside of Berms				4.61E-04	0.5
Equipment Rupture - Sustained Release Inside of Pump House Containment				1.82E-05	0.0182
Rupture of crude oil piping - outside of berms				***1.01E-04***	***0.1***
Full bore pipe rupture	2.60E-07	/m.yr	220	5.72E-05	Rijnmond, pipe rupture
Full bore valve rupture	8.76E-06	/valve.yr	5	4.38E-05	Lees, rupture or leak, Assume 10% rupture, 90% leak

EMT, Line 96 and Loading Line Faultrees: Current Operations

Description	*Base rate*	*Units*	*Multiplyer*	*Freq/yr*	*Reference or Probability over Project Lifetime*
Leak from crude oil piping - outside of berms				***1.15E-03***	***1.1***
Hole in pipe	2.63E-06	/m.yr	220	5.79E-04	Significant leak. Risk Analysis Report to the Rijnmond Public Authority, D.Reidel Publishing Co., 1981 ISBN 90-277-1393-6
Leak at large valve	7.88E-05	/valve.yr	5	3.94E-04	Lees, rupture or leak, Assume 10% rupture, 90% leak
Rupture of small valve	8.76E-06	/valve.yr	20	1.75E-04	Lees, rupture or leak, Assume 10% rupture, 90% leak
Equipment Rupture - Inside of Berms				***4.61E-04***	***0.5***
Crude oil tank failure	9.99E-05	/yr	2	2.00E-04	Atmospheric mettalic vessel - Catastrophic failure. Process Equipment Reliability Data, Centre for Chemical Process Safety, AIChE, 1989, ISBN 0-8169-0422-7
Largest credible earthquake	2.11E-03	/yr	1	2.11E-03	SBC Fire, Venoco QRA seismic analysis
Probability of earthqauke rupturing one of the tanks	1.00E-01	/demand	1	1.00E-01	Estimated
Full bore pipe rupture	2.60E-07	/m.yr	60	1.56E-05	
Full bore valve rupture	8.76E-06	/valve.yr	4	3.50E-05	
Equipment Rupture - Sustained Release Inside of Pump House Containment				***1.82E-05***	***0.02***
Pump casing failure	1.70E-03	/pump.yr	2	3.40E-03	HLID, leakage. Assume 10% rupture
Pump operation	5.25E-02	fraction	1	5.25E-02	Fraction operating time
Full bore pipe rupture	2.60E-07	/m.yr	10	2.60E-06	
Full bore valve rupture	8.76E-06	/valve.yr	4	3.50E-05	
Operator fails to observe	1.01E-01	/demand	1	1.01E-01	Rijnmond, failure to observe, and 1 hour in 20 that operator is inspecting pipeline
BARGE JOVALAN					
Large Release from Barge at Coal Oil Point				***9.88E-03***	***9.4***
Annual barge trips	23	/year	1	2.30E+01	
Barge loading fraction	5.25E-02	on demand	1	5.25E-02	Based on the time of barge loading
Spontaneous Tank Wall Failure	2.00E-06	/year	1	2.00E-06	Rijnmond, catastrophic tank wall failure
Full bore pipe rupture on barge	2.60E-07	/m.yr	10	2.60E-06	
Full bore valve rupture on barge	8.76E-06	/valve.yr	4	3.50E-05	
Operator fails to observe	1.00E-03	/demand	1	1.00E-03	Rijnmond, failure to observe
Failure of tug manuevering and grounding onshore	1.00E-03	/transit	1	1.00E-03	FEMA grounding while mooring
Mooring failure under normal conditions	1.56E-04	/mooring	1	1.56E-04	LEES, failure of lifting device
Diesel engine fails to start	3.00E-02	/demand	1	3.00E-02	Lees
Ship Collision/casuality while moored/mooring	2.00E-04	/transit	1	2.00E-04	FEMA collision while moored
Assist boat collision/casuality while moored/mooring	2.00E-04	/transit	1	2.00E-04	FEMA collision while moored
Prob of tank damage and rupture given collision, allison or grounding	2.50E-01	/demand	1	2.50E-01	DOT conditional probability of tank damage, rupture
Prob of grounding given loss of control	5.00E-01	/demand	1	5.00E-01	Estimated
Severe Wind loading	1.30E-02	/year	1	1.30E-02	Based on USCG pilot reports
Low visibility conditions	6.30E-02	/year	1	6.30E-02	Based on USCG pilot reports
Mooring system failure under stress	1.00E-01	/demand	1	1.00E-01	Estimated conditonal probability of 10%
Failure of tug manuevering in low visibility or severe wind conditions	1.00E-02	/maneuver	1	1.00E-02	DOT collision and grounding rate in harbors/bays, increased by 10 for low visibility conditions

EMT, Line 96 and Loading Line Faultrees: Current Operations

Description	*Base rate*	*Units*	*Multiplyer*	*Freq/yr*	*Reference or Probability over Project Lifetime*
Small Release from Barge at Coal Oil Point				***2.52E-02***	***22.3***
Leak at large valve	7.88E-05	/valve.yr	4	3.15E-04	
Hole in pipe	2.63E-06	/m.yr	10	2.63E-05	
Rupture of small valve	8.76E-06	/valve.yr	8	7.01E-05	
Leak from fitting/flange	2.63E-03	/valve.yr	16	4.21E-02	WASH 1400, leak from gaskets, flanges, 10% significant
Overfilling of tank	1.00E-03	/demand	23	2.30E-02	Rijnmond, failure to observe
Barge loading fraction	5.25E-02	on demand	1	5.25E-02	Based on the time of barge loading
Release from Barge In Transit				***2.64E-03***	***2.6***
Spontaneous Tank Wall Failure	2.00E-06	/year	1	2.00E-06	Rijnmond, catastrophic tank wall failure
Allision, grounding or collision while in transit at sea with subsequent spill	3.10E-04	/transit	23	7.13E-03	USCG, at sea ACG rate
Prob of tank damage and rupture given collision, allison or grounding	3.70E-01	/demand	1	3.70E-01	USCG fraction of pollution incidents, west coast
Spill Size Distribution					
Spill size < 1 gallon probability	0.54				
Spill size < 10 gallon probability	0.70				
Spill size < 100 gallon probability	0.86				
Spill size < 1000 gallon probability	0.95				
Spill size < 10,000 gallon probability	0.9979				
Spill size < 100,000 gallon probability	0.99975				
Freqeuncy of Spills of Any Size	1.98E-03	/transit			
Transits	23				
Spill size < 1 gallon frequency	2.46E-02			2.46E-02	***21.8***
Spill size > 1 gallon frequency	2.09E-02			2.09E-02	***18.9***
Spill size > 10 gallon frequency	1.36E-02			1.36E-02	***12.8***
Spill size > 100 gallon frequency	6.37E-03			6.37E-03	***6.2***
Spill size > 1000 gallon frequency	2.27E-03			2.27E-03	***2.2***
Spill size > 10,000 gallon frequency	9.55E-05			9.55E-05	***0.10***
Spill size > 100,000 gallon frequency	1.14E-05			1.14E-05	***0.011***

EMT, Line 96 and Loading Line Faultrees: Proposed Operations

Summary of Frequency Inputs					
Lifetime of project	10	years			
Average oil production over lifetime, bpd	13000	bpd over lifetime (oil only)			
Number of annual barge visits	88	per year			
Hours of loading per barge visit	20	hours			
Loading rate, bph	4200	bph			
Pipelines and EMT Summary Failure Rate and Probability Summary					
Scenario	***Freq, per year***	***Lifetime Prob, %***			
Leaks to Land Envir (not incl berm)	4.64E-02	37.1	line 96, loading line land, EMT piping no berm		
Ruptures and Large Spills to Land Envir (not incl berm)	6.76E-03	6.5	line 96, loading line land, EMT piping no berm		
Ruptures and Large Spills to Land Envir (within Tanks and pump berms)	5.31E-04	0.5	Crude tanks, valving within berm, pumps		
Leaks and Small Spills to Ocean	2.23E-01	89.3	10" pipeline, hose line, barge		
Ruptures and Large Spills to Ocean	4.11E-02	33.7	10" pipeline, hose line, barge		
Total Leaks and Small Spills (not incl berm)	2.70E-01	93.3	All leaks, except crude tanks and pumps		
Total Ruptures and Large Spills (not incl berm)	4.78E-02	38.0	All ruptures, except crude tanks and pumps		
Detailed Calculations					
Description	***Base rate***	***Units***	***Multiplyer***	***Freq/yr***	***Reference or Probability over Project Lifetime***
PIPELINE FAILURE RATES					
Pipeline Only					
Loading Line Pipeline - Land Rate (12" portion)					
CSFM for this pipeline, leak	5.64E-02	per mile-year	0.15	8.28E-03	7.9
CSFM for this pipeline, rupture	1.02E-02	per mile-year	0.15	1.49E-03	1.5
Loading Line Pipeline - Ocean Rate (10" portion)					
CSFM for this pipeline, leak	5.64E-02	per mile-year	0.54	3.02E-02	26.0
CSFM for this pipeline, rupture	1.02E-02	per mile-year	0.54	5.43E-03	5.3
Line 96 Pipeline - Failure rates					
CSFM for this pipeline, leak	1.13E-02	per mile-year	3.1	3.50E-02	29.6
CSFM for this pipeline, rupture	2.03E-03	per mile-year	3.1	6.31E-03	6.1
Line 96 SCADA - failure				***1.93E-03***	***1.9***
Phone line failure	2.28E-04	demand	1	2.28E-04	Estimated 8 hours per year down time
Pump shutdown failure	1.00E-04	on demand	1	1.00E-04	Rijnonmd, failure to stop on demand
Actuated valve failure	1.00E-03	on demand	1	1.00E-03	Lees, failure to operate on demand
Pressure Switch	1.00E-04	on demand	1	1.00E-04	Rijnonmd, failure on demand
Operator Restarts system, override SCADA	5.00E-04	on demand	1	5.00E-04	Rijnmond, falilure to take action on an alarm. Conditions to inspect line after each alarm.

EMT, Line 96 and Loading Line Faultrees: Proposed Operations

PIPELINE AND COMPONENT FAILURE RATES					
Description	***Base rate***	***Units***	***Multiplyer***	***Freq/yr***	***Reference or Probability over Project Lifetime***
Summary					
Line 96 leak				3.55E-02	29.9
Line 96 rupture				6.35E-03	6.2
Loading line leak to land (includes leak at all times and ruptures when not operating)				1.10E-02	10.4
Loading line leak to ocean (includes leak at all times and ruptures when not operating)				1.99E-01	86.3
Loading line rupture to land (includes only ruptures when operating)				3.06E-04	0.3
Loading line rupture to ocean (includes only ruptures when operating)				3.30E-03	3.2
Loading line leak				2.10E-01	87.7
Loading line rupture				3.61E-03	3.5
Loading Line Pipeline - Land portion - Leak- not operating				***8.05E-03***	***7.7***
Pipeline Leak				8.28E-03	
Leak at large valve	7.88E-05	/valve.yr	3	2.37E-04	
Rupture of small valve	8.76E-06	/valve.yr	5	4.38E-05	
Pipeline Rupture				1.49E-03	
Full bore valve rupture	8.76E-06	/valve.yr	3	2.63E-05	
Operational fraction	2.01E-01	on demand	1	2.01E-01	Based on the time of barge loading
Loading Line Pipeline - Land portion - Rupture not operating				***1.22E-03***	***1.2***
Pipeline Rupture				1.49E-03	
Full bore valve rupture	8.76E-06	/valve.yr	4	3.50E-05	
Operational fraction	2.01E-01	on demand	1	2.01E-01	Based on the time of barge loading
Loading Line Pipeline - Land portion - Leak while operating				***1.72E-03***	***1.7***
Pipeline Leak				8.28E-03	
Leak at large valve	7.88E-05	/valve.yr	3	2.37E-04	
Rupture of small valve	8.76E-06	/valve.yr	5	4.38E-05	
Operational fraction	2.01E-01	on demand	1	2.01E-01	Based on the time of barge loading
Loading Line Pipeline - Land portion - Rupture while operating				***3.06E-04***	***0.3***
Pipeline Rupture				1.49E-03	
Full bore valve rupture	8.76E-06	/valve.yr	4	3.50E-05	
Operational fraction	2.01E-01	on demand	1	2.01E-01	Based on the time of barge loading
Loading Line Pipeline - Ocean portion - Leak- not operating				***1.57E-01***	***79.3***
Pipeline Leak				3.02E-02	
Leak from hose	1.10E-01	/hose-yr	1	1.10E-01	CCPS 89 for rupture. Assume 10% rupture and annual maintenace
Leak from hose flanges	8.76E-05	/flange-yr	7	6.13E-04	
Leak at large valve	7.88E-05	/valve.yr	1	7.88E-05	
Rupture of small valve	8.76E-06	/valve.yr	0	0.00E+00	
Pipeline Rupture				5.43E-03	
Rupture from hose	1.10E-02	/hose-yr	1	1.10E-02	CCPS 89 for rupture. Assume 10% rupture and annual maintenace
Full bore valve rupture	8.76E-06	/valve.yr	1	8.76E-06	

EMT, Line 96 and Loading Line Faultrees: Proposed Operations

Description	***Base rate***	***Units***	***Multiplyer***	***Freq/yr***	***Reference or Probability over Project Lifetime***
Loading Line Pipeline - Ocean portion - Rupture not operating				***1.31E-02***	***12.3***
Pipeline Rupture				5.43E-03	
Rupture from hose	1.10E-02	/hose-yr	1	1.10E-02	CCPS 89 for rupture. Assume 10% rupture and annual maintenace
Full bore valve rupture	8.76E-06	/valve.yr	1	8.76E-06	
Operational fraction	2.01E-01	on demand	1	2.01E-01	Based on the time of barge loading
Loading Line Pipeline - Ocean portion - Leak while operating				***2.83E-02***	***24.6***
Pipeline Leak				3.02E-02	
Leak from hose	1.10E-01	/hose-yr	1	1.10E-01	CCPS 89 for rupture. Assume 10% rupture and annual maintenace
Leak from hose flanges	8.76E-05	/flange-yr	7	6.13E-04	
Leak at large valve	7.88E-05	/valve.yr	1	7.88E-05	
Rupture of small valve	8.76E-06	/valve.yr	0	0.00E+00	
Operational fraction	2.01E-01	on demand	1	2.01E-01	Based on the time of barge loading
Loading Line Pipeline - Ocean portion - Rupture while operating				***3.30E-03***	***3.2***
Pipeline Rupture				5.43E-03	
Rupture from hose	1.10E-02	/hose-yr	1	1.10E-02	CCPS 89 for rupture. Assume 10% rupture and annual maintenace
Full bore valve rupture	8.76E-06	/valve.yr	1	8.76E-06	
Operational fraction	2.01E-01	on demand	1	2.01E-01	Based on the time of barge loading
Line 96 Pipeline - Leak				***3.55E-02***	***29.9***
Pipeline Leak				3.50E-02	
Leak at large valve	7.88E-05	/valve.yr	5	3.94E-04	
Rupture of small valve	8.76E-06	/valve.yr	10	8.76E-05	
Line 96 Pipeline - Rupture				***6.35E-03***	***6.2***
Pipeline Rupture				6.31E-03	
Full bore valve rupture	8.76E-06	/valve.yr	5	4.38E-05	
EMT FAILURE RATES				**Freq/yr**	
Summary					
Rupture of crude oil piping - outside of berms				1.01E-04	0.1
Leak from crude oil piping - outside of berms				1.15E-03	1.1
Equipment Rupture - Inside of Berms				4.61E-04	0.5
Equipment Rupture - Sustained Release Inside of Pump House Containment				6.98E-05	0.0697
Rupture of crude oil piping - outside of berms				***1.01E-04***	***0.1***
Full bore pipe rupture	2.60E-07	/m.yr	220	5.72E-05	Rijnmond, pipe rupture
Full bore valve rupture	8.76E-06	/valve.yr	5	4.38E-05	Lees, rupture or leak, Assume 10% rupture, 90% leak

EMT, Line 96 and Loading Line Faultrees: Proposed Operations

Description	Base rate	Units	Multiplyer	Freq/yr	Reference or Probability over Project Lifetime
Leak from crude oil piping - outside of berms				***1.15E-03***	***1.1***
Hole in pipe	2.63E-06	/m.yr	220	5.79E-04	Significant leak. Risk Analysis Report to the Rijnmond Public Authority, D.Reidel Publishing Co., 1981 ISBN 90-277-1393-6
Leak at large valve	7.88E-05	/valve.yr	5	3.94E-04	Lees, rupture or leak, Assume 10% rupture, 90% leak
Rupture of small valve	8.76E-06	/valve.yr	20	1.75E-04	Lees, rupture or leak, Assume 10% rupture, 90% leak
Equipment Rupture - Inside of Berms				***4.61E-04***	***0.5***
Crude oil tank failure	9.99E-05	/yr	2	2.00E-04	Atmospheric mettalic vessel - Catastrophic failure. Process Equipment Reliability Data, Centre for Chemical Process Safety, AIChE, 1989, ISBN 0-8169-0422-7
Largest credible earthquake	2.11E-03	/yr	1	2.11E-03	SBC Fire, Venoco QRA seismic analysis
Probability of earthqauke rupturing one of the tanks	1.00E-01	/demand	1	1.00E-01	Estimated
Full bore pipe rupture	2.60E-07	/m.yr	60	1.56E-05	
Full bore valve rupture	8.76E-06	/valve.yr	4	3.50E-05	
Equipment Rupture - Sustained Release Inside of Pump House Containment				***6.98E-05***	***0.1***
Pump casing failure	1.70E-03	/pump.yr	2	3.40E-03	HLID, leakage. Assume 10% rupture
Pump operation	2.01E-01	fraction	1	2.01E-01	Fraction operating time
Full bore pipe rupture	2.60E-07	/m.yr	10	2.60E-06	
Full bore valve rupture	8.76E-06	/valve.yr	4	3.50E-05	
Operator fails to observe	1.01E-01	/demand	1	1.01E-01	Rijnmond, failure to observe, and 1 hour in 20 that operator is inspecting pipeline
BARGE JOVALAN					
Large Release from Barge at Coal Oil Point				***3.78E-02***	***31.5***
Annual barge trips	88	/year	1	8.80E+01	
Barge loading fraction	2.01E-01	on demand	1	2.01E-01	Based on the time of barge loading
Spontaneous Tank Wall Failure	2.00E-06	/year	1	2.00E-06	Rijnmond, catastrophic tank wall failure
Full bore pipe rupture on barge	2.60E-07	/m.yr	10	2.60E-06	
Full bore valve rupture on barge	8.76E-06	/valve.yr	4	3.50E-05	
Operator fails to observe	1.00E-03	/demand	1	1.00E-03	Rijnmond, failure to observe
Failure of tug manuevering and grounding onshore	1.00E-03	/transit	1	1.00E-03	FEMA grounding while mooring
Mooring failure under normal conditions	1.56E-04	/mooring	1	1.56E-04	LEES, failure of lifting device
Diesel engine fails to start	3.00E-02	/demand	1	3.00E-02	Lees
Ship Collision/casuality while moored/mooring	2.00E-04	/transit	1	2.00E-04	FEMA collision while moored
Assist boat collision/casuality while moored/mooring	2.00E-04	/transit	1	2.00E-04	FEMA collision while moored
Prob of tank damage and rupture given collision, allison or grounding	2.50E-01	/demand	1	2.50E-01	DOT conditional probability of tank damage, rupture
Prob of grounding given loss of control	5.00E-01	/demand	1	5.00E-01	Estimated
Severe Wind loading	1.30E-02	/year	1	1.30E-02	Based on USCG pilot reports
Low visibility conditions	6.30E-02	/year	1	6.30E-02	Based on USCG pilot reports
Mooring system failure under stress	1.00E-01	/demand	1	1.00E-01	Estimated conditonal probability of 10%
Failure of tug manuevering in low visibility or severe wind conditions	1.00E-02	/maneuver	1	1.00E-02	DOT collision and grounding rate in harbors/bays, increased by 10 for low visibility conditions

EMT, Line 96 and Loading Line Faultrees: Proposed Operations

Description	*Base rate*	*Units*	*Multiplyer*	*Freq/yr*	*Reference or Probability over Project Lifetime*
Small Release from Barge at Coal Oil Point				***9.65E-02***	***61.9***
Leak at large valve	7.88E-05	/valve.yr	4	3.15E-04	
Hole in pipe	2.63E-06	/m.yr	10	2.63E-05	
Rupture of small valve	8.76E-06	/valve.yr	8	7.01E-05	
Leak from fitting/flange	2.63E-03	/valve.yr	16	4.21E-02	WASH 1400, leak from gaskets, flanges, 10% significant
Overfilling of tank	1.00E-03	/demand	88	8.80E-02	Rijnmond, failure to observe
Barge loading fraction	2.01E-01	on demand	1	2.01E-01	Based on the time of barge loading
Release from Barge In Transit				***1.01E-02***	***9.6***
Spontaneous Tank Wall Failure	2.00E-06	/year	1	2.00E-06	Rijnmond, catastrophic tank wall failure
Allision, grounding or collision while in transit at sea with subsequent spill	3.10E-04	/transit	88	2.73E-02	USCG, at sea ACG rate
Prob of tank damage and rupture given collision, allison or grounding	3.70E-01	/demand	1	3.70E-01	USCG fraction of pollution incidents, west coast
Spill Size Distribution Approach					
Spill size < 1 gallon probability	0.54				
Spill size < 10 gallon probability	0.70				
Spill size < 100 gallon probability	0.86				
Spill size < 1000 gallon probability	0.95				
Spill size < 10,000 gallon probability	0.9979				
Spill size < 100,000 gallon probability	0.99975				
Freqeuncy of Spills of Any Size	1.98E-03	/transit			
Transits	88				
Spill size < 1 gallon frequency	9.40E-02			9.40E-02	***60.9***
Spill size > 1 gallon frequency	8.01E-02			8.01E-02	***55.1***
Spill size > 10 gallon frequency	5.22E-02			5.22E-02	***40.7***
Spill size > 100 gallon frequency	2.44E-02			2.44E-02	***21.6***
Spill size > 1000 gallon frequency	8.70E-03			8.70E-03	***8.3***
Spill size > 10,000 gallon frequency	3.66E-04			3.66E-04	***0.36***
Spill size > 100,000 gallon frequency	4.35E-05			4.35E-05	***0.044***

Major Oil Spills Affecting US Waters: 1984-2004

Date	Name	Source	Locations	Product	Amount, Gal	Causes	Total Known Costs, millions
3/19/1984	Mobiloil	Tanker	Columbia River, OR	#6 Fuel	170,000	Steering failure and grounding	12.9
7/30/1984	Alvenus	Tanker	Cameron, LA	Oil	2,730,000	Grounding	-
9/28/1985	Grand Eagle	Tanker	Marcus Hook, PA	Oil	434,994	Grounding	-
10/31/1984	Puerto Rican	Tanker	Fallarones, CA	Oil	1,470,000	Explosion and fire	-
11/24/1985	SFI 41	Barge	Mississippi	Fuel Oil	684,600	Allison with bridge	-
12/21/1985	Arco Anchorage	Tanker	Port Angeles, WA	Crude Oil	239,000	Grounding in harbor	23.8
1/28/1986	Apex Houston	Barge	Gulf of the Farallones,	Crude Oil	25,000	Failed hatch cover, leak while in transit	9.9
3/7/1986	Texas	Barge	Mississippi	Crude	714,000	Grounding	-
12/4/1986	Amazon Venture	Tanker	Savannah River, GA	#6 Fuel	500,000	Ballast valve failures	3.8
7/2/1987	Glacier Bay	Tanker	Cook Inlet, AK	Crude Oil	207,000	Grounding	90.5
9/21/1987	Pac Baronessa	Vessel	Pt. Conception, CA	Fuel Oil	386,400	Collision	-
10/10/1987	YUM II Zapoteca	Well	Gulf of Mexico	Crude	2,462,880	Well blowout	-
1/31/1988	MCN-5	Barge	Shannon Pt, WA	Oil	67,368	Sinking	-
4/22/1988	Athenian Venture	Tanker	Newfoundland, Canada	Gasoline	10,500,000	Explosion	-
7/13/1988	Nord Pacific	Tanker	Corpus Christi, TX	Crude	644,700	Collision with dock	-
9/3/1988	ESSO Puerto Rico	Tanker	Mississippi	Carbon black	966,000	Hit anchor	-
12/22/1988	Nestucca	Barge	Grays Harbor, WA	#6 Fuel	23,100	Collision from towing tug	28.9
12/26/1988	UMTB 283	Barge	Alluetin Islands, AK	Diesel	2,000,040	Sinking, anchor puncture	-
3/24/1989	Exxon Valdez	Tanker	Prince William Sound, AK	Crude Oil	11,000,000	Navigational error, grounding	11,859.8
6/23/1989	World Prodigy	Tanker	Narragansett Bay, RI	#2 Fuel	288,666	Grounding	9.3
6/24/1989	Presidente Rivera	Tanker	Delaware River	#6 Fuel	307,000	Grounding	8.0
1/2/1990	Exxon Bayway	Pipeline	Arthur Kill, NY	#2 Fuel	567,000	Rupture	71.4
2/7/1990	American Trader	Tanker	Huntington Beach, CA	Crude Oil	398,000	Grounding on own anchor	71.5
3/6/1990	Cibro Savanah	Tanker	Linden, NJ	Oil	127,000	Exploded	-
6/7/1990	BT Nautilus	Tanker	Kill Van Kull, NY	#6 Fuel	252,800		29.8
6/8/1990	Mega Borg	Tanker	Gulf of Mexico	Crude Oil	5,100,000	Explosion during lightering	6.7
7/28/1990	Apex Towing/Shinoussa	Barge	Galveston Bay, TX	Catalytic Stock	694,000	Collision	7.4

Major Oil Spills Affecting US Waters: 1984-2004

Date	Name	Source	Locations	Product	Amount, Gal	Causes	Total Known Costs, millions
9/16/1990	Jupiter	Tanker	Bay City, MI	gasoline	840,000	Fire and explosion during offloading	7.6
2/22/1991	Texaco Anacortes	Facility	Anacortes, WA	Crude Oil	210,000		11.8
7/22/1991	Tenyo Maru	Fishing Vessel	Neah Bay, WA	Fuel Oil	173,000	Collision	17.5
9/29/1992	Greenhill	Well	Timbalier Bay, LA	Crude Oil	122,000	Well blowout	3.1
12/21/1992	RTC-380	Barge	Groton, CN	#2 Fuel	27,000		0.5
3/28/1993	Colonial Pipeline	Pipeline	Sugarland Run, VA	Diesel Fuel	407,000		33.0
8/10/1993	Bouchard 155	Tanker	Tampa Bay, FL	Fuel Oil	336,000	Collision	-
1/7/1994	Morris J. Berman	Barge	San Juan, PR	#6 Fuel	800,000	Grounding	183.2
1/10/1994	An Ping	Freighter	Longview, WA	#6 fuel	26,000		0.5
1/17/1994	Arco Pipeline	Pipeline	Santa Clara River	Crude Oil	190,000		20.5
10/1/1994	-	Pipelines	TX	Oil	320,000	Flooding, washed out areas	-
10/8/1994	-	Pipeline	Portland, TX	Oil	90,000	Rupture of pipeline	-
11/16/1994	-	Pipeline	Gulf of Mexico	Oil	177,000	Rupture	-
12/23/1994	Berry Petroleum	Pipeline	McGrath Lake, CA	Crude Oil	87,000		4.4
7/1/1995	Enif/Alexia	Tankers	Gulf of Mexico	Fuel Oils	95,000	Collision	-
7/22/1995	Jahre Spray	Tanker	Delaware River Crude	Oil	56,000	Transfer operations weather damage	0.3
10/11/1995	-	Barge	Morco, LA	Oil	195,000	Collision	-
1/19/1996	North Cape	Barge	Point Judith, RI	Fuel Oil	828,000	Tug caught fire, drifting, grounding	-
3/18/1996	Buffalo 292	Barge	Galveston Bay, TX	Fuel Oil	176,000	structural failure	-
9/27/1996	Julie N	Barge	Portland, MN	Fuel Oil	166,000	Allison with bridge	-
10/28/1996	SS Cape Mohican	Vessel	San Francisco, CA	Fuel Oil	98,000	Maintenace error while docked	-
5/15/1997	RTC 420	Barge	Carteret, NJ	Oil	47,000	Tank overfilling	-
11/26/1997	Kuroshima	Vessel	Alaska	Oil	39,000	Broke mooring, severe storms, grounding	-
1/23/1998	Adriatic Sea	Fishing	Pacific	Diesel	118,000	Sinking	-
6/27/1998	CTCO 211	Barge	Darrow, LA	Crude	154,000	Collision with vessel	-

Major Oil Spills Affecting US Waters: 1984-2004

Date	Name	Source	Locations	Product	Amount, Gal	Causes	Total Known Costs, millions
1/12/1999	MM 100	Barge	Port Fourchon, LA	Diesel	51,000	Collision with towing tug	-
1/29/1999	WTC 2014	Barge	Bayou Sorrel, LA	Gasoline	64,000	Collision with mooring bouy	-
2/4/1999	New Carrisa	Tanker	Coos Bay, OR	Fuel Oil	150,000	Grounding	-
6/10/1999	-	Pipeline	Bellingham, WA	Gasoline	236,000	Rupture	-
1/21/2000	-	Pipeline	Gulf of Mexico	Crude	77,000	Puncture by anchor	-
4/7/2000	-	Pipeline	Aguasco, MA	Oil	140,000	persistent leak	-
6/8/2000	Posavina	Tanker	Massachusetts	Fuel oil	59,000	Damage by tug	-
6/12/2000	NMS 111	Barge	Houston ship channel	Fuel Oil	80,000	Tank overfilling	-
11/8/2000	Westchester	Tanker	Mississippi River	Crude	538,000	Explosion, Loss of steerage, Grounding	-
3/14/2001	MV Genmar Hector	Tanker	Texas City	Crude	31,000	High winds broke loading arms	-
9/22/2001	NMS 1486	Barge	Houston Ship Channel	Fuel Oil	50,000	Collision	-
11/7/2001	WTC 105	Barge	Ohio River	Gasoline	125,000	Damage while moored	-
4/27/2003	Bouchard No. 120	Barge	Buzzards bay, RI	Oil	98,000	Underwater object, bottom puncture	-
11/26/2004	Athos 1	Tanker	Delaware River	Oil	30,000	Underwater puncture	-

Source: NOAA 1999, NOAA 1992, Numerous spill specific web sites